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短　報

Kink in the Cd-PO_4 plot near the Okinawa Island observed in the summer of 2001

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Abstract The relationship between cadmium (Cd) and phosphate (PO_4) was investigated in an area near the Okinawa Island in June 2001. A plot of these constituents showed two straight lines with a clear deviation (kink) at a PO_4 concentration of around 0.4 μM. The forces that caused the existence of the kink in the plot are not clear; however, the discontinuity of the water mass across this layer, as deduced from the T-S diagram, seems to be at least partially responsible.

Key words: Cd, PO_4, Kink, Okinawa Island

The distribution of cadmium (Cd) in the ocean is strongly correlated with that of phosphate (PO_4). It has been reported that the behavior of Cd in seawater is regulated by marine biogeochemical processes, such as an uptake by phytoplankton in surface waters, consequential decomposition of the produced organic matter, and remineralization in deep waters, which indicates the importance of studying the behavior of bio-limiting constituents such as Cd and PO_4 for a better understanding of productivity in the sea. Early studies showing a clear linearity with a 0-intercept in the plot of Cd and PO_4 were conducted in the Pacific Ocean with a slope of around 0.3-0.36 nM/μM (e.g., Bruland, 1980). However, more recent studies have shown that not all relationships between the two constituents have a clear linearity. In fact, a deviation (kink) in the plot has been reported (Kudo *et al.*, 1996; Abe, 2001), and Abe (2002a) shown the kink in the Cd-PO_4 plot in the subtropical area including the southern Okinawa Trough. The objective of this paper is to report the kink in the Cd-PO_4 plot observed at a depth of 170 to 180m on the northern part of the Okinawa Trough in summer of 2001.

Water samples were taken vertically at St. 1 (28°10N, 127°13E: water depth, 1,070 m) from 0 to 250m every 10 meters using acid-cleaned rosette-mounted 1.7L Niskin bottles aboard the R/V Yoko-Maru of the Seikai National Fisheries Research Institute in June 2001 (Fig. 1). The water samples were transferred to acid-cleaned 250mL polyethylene bottles and frozen

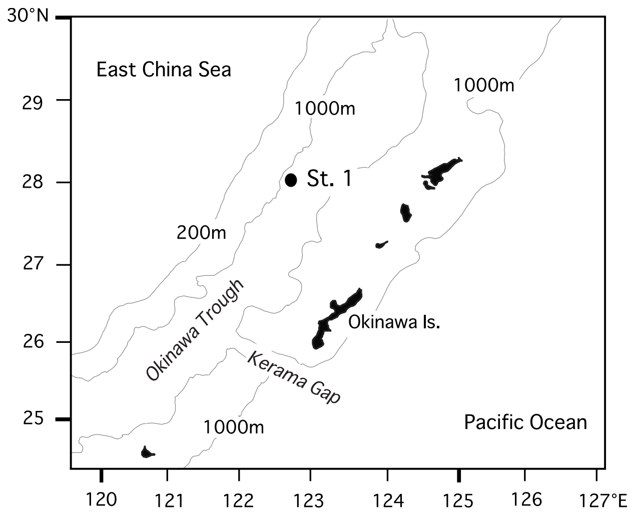

Fig. 1. Sampling sites in this study

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immediately until analysis in the laboratory. Details of the analytical method for the determination of Cd and PO_4 are given in Abe (2002a). The analytical error in a single determination of dissolved cadmium was estimated as 2.4% at a concentration of 76pM, and 1.4% at a concentration of 1.33 μM for phosphate. Temperature and salinity were measured by a Sea Bird SBE9plus CTD up to 300m. Salinity increased with depth from the surface to a maximum of around 34.8 observed at 163m (Figs. 2, 3). Below 163m, the salinity decreased to 188m and increased again to 239m, and the change in the salinity was much steeper between 163m and 188m, which suggested the penetration of low salinity water into this layer. Below 239m, the salinity and temperature decreased gradually with depth. The vertical profile of dissolved Cd was typical of that of the nutrient, PO_4 (Fig. 4). In fact, Cd was depleted in the surface water but increased in concentration with depth. This distributional

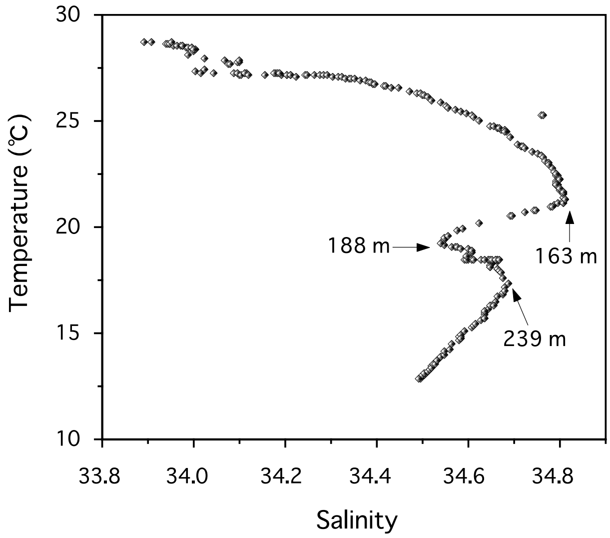

Fig. 2. T-S diagram. The plotted points were arranged every one-meter from the surface to 300m. Numbers in the figure indicate the water depth corresponding to each point.

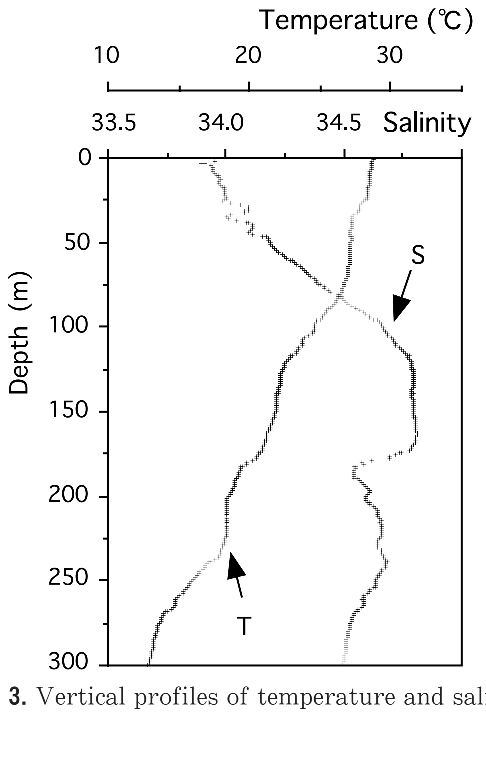

Fig. 3. Vertical profiles of temperature and salinity

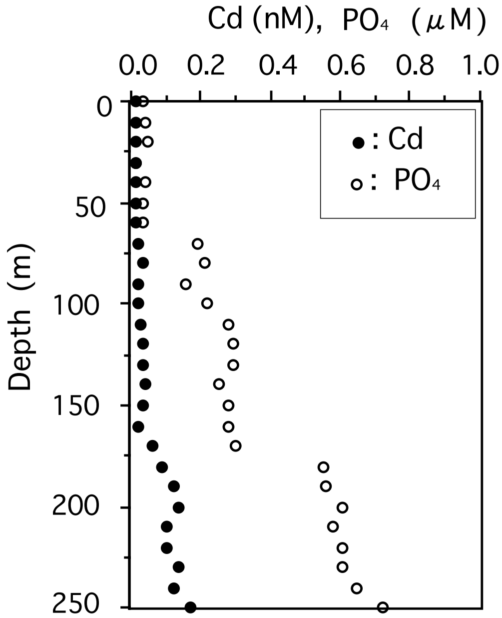

Fig. 4. Vertical profiles of Cd and PO_4

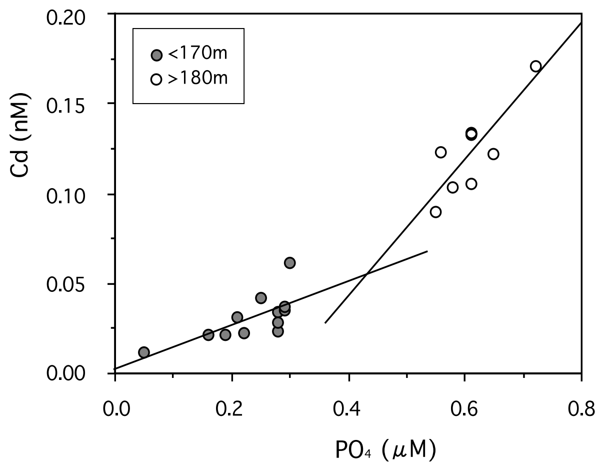

Fig. 5. Plot of Cd and PO_4. A clear kink was shown across the PO_4 concentration of around 0.4 μM corresponding to a water depth between 170m and 180m.

pattern generally agrees with a previously reported trend in the open oceans (e.g., Pai and Chen, 1994). Fig. 5 shows the relationship between Cd and PO_4. As shown, two clusters were recognizable in the plot across the PO_4 concentration of around 0.4 μM, and regression analyses were calculated for each group as follows:

$$Cd = 0.0020 + (0.12 \times 10^{-3}) \times PO_4 \quad (r = 0.70) \cdots\cdots (<170m) \qquad (1)$$

$$Cd = -0.11 + (0.38 \times 10^{-3}) \times PO_4 \quad (r = 0.85) \cdots\cdots (>180m) \qquad (2)$$

In the calculation of the regression line, a significant figure was determined to be two digits due to the low concentrations (low accuracy) of the observed Cd and PO_4 in this study. The regression line up to 170m showed a straight line going through near the origin and the slope of 0.12 (nM/μM), which was in general agreement with the values reported by Abe (2002a). Uptake-remineralization ratios to oxygen (molar ratio) were reported to be 0.00134×10^{-3} and 0.00684 for Cd and PO_4, respectively, in this study area (Abe, 2002b), and from these values, the Cd/PO_4 ratio in the uptake-remineralization process was calculated to be 0.19 (nM/μM). These two values seemed to be similar, which suggested that the biogeochemical (uptake-remineralization) process regulated the relationship between the two constituents in the shallow layer (<170m). Below 180m, the linearity was also maintained in the plot, with a steeper slope of 0.38 (nM/μM) that was attributable to the physical mixing with deeper water. Abe (2002a) also reported the existence of a kink at a PO_4 concentration of approximately 0.2 μM in the Cd-PO_4 plot near the Ryukyu Islands, corresponding to the discontinuity of the water mass at a water depth of around 250m～300m across the North Pacific Subtropical Mode Water. The water depth at which the deviation (kink) was observed in this study corresponded to the layer with a steep change in salinity that was attributable to the penetration of a different less saline water (Figs. 2, 3). The less saline water was considered to be originated from the continental shelf water (Nitani, 1972), and this penetration possibly led to the discontinuity of the water type across the layer. In conclusion, although the driving forces causing the discontinuity in the plot remain obscure, a clear kink was certainly observed in this study in the relationship between the two constituents.

Acknowledgments

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